

REMARKS

This action is in response to the Office Action mailed on August 1, 2003, a Notice of Appeal filed on November 3, 2003, and a subsequent telephone interview held in December 2003. Claims 1-12 are pending in the case. The Examiner issued a final restriction requirement. The Examiner rejected claims 1-9 under 35 U.S.C. 103(a) as being unpatentable over U.S. Patent Application Publication No. 2002/0024780 to Mao et al. (hereinafter "Mao") in view of U.S. Patent Application Publication No. 2001/0013997 to Sasaki et al. (hereinafter "Sasaki"). The Examiner rejected claims 10 and 11 under 35 U.S.C. 103(a) as being unpatentable over Mao in view of Sasaki and further in view of U.S. Patent Application Publication No. 2002/0054463 to Mukoyamma et al. (hereinafter "Mukoyamma"). The Examiner rejected claim 12 under 35 U.S.C. 103(a) as being unpatentable over Mao in view of Sasaki and further in view of U.S. Patent Application Publication No. 2001/0014412 to Jongill et al. (hereinafter "Jongill"). Claims 3-6 have been cancelled and claims 13-15 have been added. The amended and new claims are believed to be in condition for allowance, and Applicant respectfully requests the prompt allowance of claims 1-2 and 7-15.

Claim Rejections

Claims 1-12 stand rejected under 35 U.S.C. 103(a) as being unpatentable over Mao in view of Sasaki, Mukoyama and Jongill.

Applicant has amended claims 1, 2, 7, 8, and 12 to clarify what the Applicant regards as the invention. Specifically, Applicant has amended these claims to clarify that the oxidized metallic films are *in-situ* oxidized. This process is fully described in the specification on page 6 lines 12-24, and page 14, lines 6-14.

To avoid potential confusion with metal oxides that do not produce the same level of resistance as the *in-situ* oxidized metallic films, claim 1 recites "the gap layer comprising a plurality of *in-situ* oxidized metallic films." *In-situ* oxidized metallic films are made by sputter-depositing a pure metal in a high vacuum and subsequently introducing oxygen to the pure metal film to fully oxidize the metal. Preferably, the pure metal layer is sputtered using a thickness small enough to ensure that the layer is completely oxidized once the oxygen is introduced *in-*

situ. Typically, this means that the pure metal layer is no more than ten angstroms thick. As pointed out in the specification, multiple layers are *in-situ* oxidized in order to achieve the desired thickness for the gap layer. See specification page 14, lines 11-14.

Full oxidation of each metal layer provides an optimal high resistance through the gap layer. As described in the specification, *in-situ* oxidation is very different from other methods of making metal oxides. First, a metal film is deposited using reactive DC-pulsed magnetron sputtering (deposition phase). See Specification page 14, line 9. After the reactive DC-pulsed sputtering, the film is subjected to oxygen gas such that full oxidation occurs (oxidation phase). See Specification page 14, line 10.

Other well known techniques exist for forming of metal oxides. Unfortunately, these methods do not produce layers of metal oxide that are fully oxidized or having electrical resistance as high as with *in-situ* oxidation of a pure, thin metal layer as in the claimed invention. There are four methods of forming metal oxide films such as Al_2O_3 films:

1. Direct Physical Vapor Deposition (PVD) sputter-deposition from an Al_2O_3 target;
2. Reactive PVD sputter-deposition in oxygen gas from an Al;
3. Chemical Vapor Deposition (CVD) where two gases are combined, one gas may be H_2O , N_2O or H_2O_2 , the other may be $\text{Al}(\text{CH}_3)_3$ or Al_2Cl_3 the resulting Al_2O_3 is deposited onto a substrate;
4. and Direct PVD sputter-deposition of a metallic Al film from an Al target and *in-situ* oxidation of the Al film (this is the method used in the present invention).

The first three methods share the same difficulty in achieving full oxidation. In other words, stoichiometric Al_2O_3 cannot be attained, thus leaving unwanted, non-oxidized Al or other metal atoms. As a result, the metal oxide films formed with these three methods will not provide a very high resistance needed for very thin gap layers used for ultrahigh-density magnetic recording. The degree to which the metal is oxidized according to the present invention, or any of the above methods is extremely difficult to quantify. However, the degree of oxidation may be derived by understanding the physical characteristics of the metal oxide that results.

In method 1 above, the quality of the gap layer depends on the purity of the Al_2O_3 target. It is difficult to attain a good-quality gap layer since only a low-purity Al_2O_3 target can be fabricated with low-vacuum sintering of low-purity oxide powders.

In method 2, the quality of the gap layer depends on the purity of the Al target and the oxygen doping extent during the reactive sputtering. In spite of the fact that a high-purity Al target can be fabricated with high-vacuum casting of a high-purity Al melt phase, it is still difficult to attain a good-quality gap layer since the oxygen doping extent cannot be as high as desired. At such a high oxygen doping extent, no oxide can be deposited since the deposition rate is nearly zero.

In method 3, the quality of the gap layer depends on the purity of the gases and an early stage of the CVD process. It may be difficult to attain a good-quality gap layer since unwanted Al, H_2O , N_2 , H_2 , C or Cl_2 may also be introduced into the oxide layer, and stoichiometric Al_2O_3 cannot be absorbed on a dissimilar surface in the early stage.

In method 4, the present invention, the quality of the gap layer depends on the purity of the Al target and the *in situ* oxidation extent after the deposition of a very thin Al film. It is feasible to attain a good-quality gap layer since a high-purity Al target can be fabricated with high-vacuum casting of a high-purity Al melt phase, and the *in-situ* oxidation extent can be as high as desired. The very thin Al film with a closely packed face-centered-cubic crystalline lattice is first formed. Oxygen atoms are then introduced to fill vacancy sites of the crystalline lattice, and chemically bond all the Al for full oxidation. It should be noted that excessive oxygen gases can be introduced to ensure the very much needed full oxidation.

This lattice is thin enough that the O atoms enter the lattice, fill vacancy sites, and chemically join with the Al atoms to form Al-O compounds, i.e. complete oxidation.

In addition, the degree of oxidation may be derived by analyzing the physical characteristics of such layers when used in applications other than as a gap layer which requires the layer to be an optimal insulator (very high electrical resistance). For example, attempts have been made to use metal oxides for the barrier layer in a TMR (Tunneling Magnetoresistance) sensor. In order for a TMR sensor to work, there must be tunneling effects. To produce tunneling effects, there must be substantially no current flow through the barrier layer and there

must be no metal elements in the barrier layer. Only a pure metal oxide will provide for no metal elements and no current flow (very high resistance) such that conduction electrons will be forced to travel only by making quantum jumps (“the tunneling effect”).

Attempts to use a barrier layer made of metallic oxide such as Al_2O_3 formed using the CVD process have been made and are explained in the paper entitled “ALCVD AlO_x Barrier Layers for Magnetic Tunnel Junction Applications” (referred to herein as “ALCVD paper”) by R. Bubber, M. Mao, T. Schneider, H. Hegde, K. Sin, S. Fundada, and S. Shi submitted herewith as exhibit A. This paper indicates that Al_2O_3 metallic oxide formed using CVD as taught by Sasaki fails to provide the high electrical resistance necessary to allow for the tunneling effect. See ALCVD paper page 3, left column, first line of first full paragraph, “The low junction resistance and the ohmic I - V feature indicate that the corresponding AlO_x barrier layers are Al-rich, deviating from the stoichiometric Al_2O_3 .” In fact, Al_2O_3 metallic oxide formed with the three prior-art methods all fail to provide the high electrical resistance necessary to allow for the tunneling effect.

In contrast, a barrier layer formed using a metallic oxide formed using *in-situ* oxidation has been shown to prevent current flow across the layer and substantially eliminate metal elements such that tunneling effects are achieved. The paper entitled “A Tunneling Magnetoresistance Sensor Overlaid with a Longitudinal Bias Stack” (referred to herein as “Tunneling paper”) by Tsann Lin, Daniele Mauri, and Philip M. Rice submitted herewith as exhibit B demonstrates this. Specifically, the barrier layer is made of Al-O and formed by *in-situ* oxidation. See Tunneling paper page 346, end of first paragraph and page 347, second sentence, top of right column. The paper demonstrates that a tunneling effect is achieved using a barrier layer of metallic oxide formed by *in-situ* oxidation.

Therefore, because a metal oxide formed using the CVD process as taught in Sasaki fails to allow for tunneling effects when used as a barrier layer in a TMR sensor and metallic oxides formed using the *in-situ* process allow for tunneling effects when used as the same layer, we can derive an understanding of differences between a metal oxide layer formed using the CVD process and one formed using *in-situ* oxidation. Because tunneling effects require substantially no metal elements and no current flow, it is clear that the *in-situ* oxidized metallic layer has a

higher resistance than a CVD metal oxide. Similarly, metal oxides formed using methods 1 and 2 above also fail to allow a tunneling effect. Consequently, the *in-situ* oxidized metallic layer is physically different, patentably different, and a superior insulator over metal oxides formed using conventional methods.

It is important to understand that during the deposition phase, the thickness of the metal is controlled so that the metal remains thin enough for the oxygen to fully chemically bond the metal. For example, the metal may be sputtered to no more than about ten Angstroms. See Specification page 14, line 13. Of course higher pressure and time of exposure to oxygen may be used to attain higher oxygen density in the metallic film.

It is for these reasons that the references to “oxidized metallic films” are replaced by “*in-situ* oxidized metallic films.” In addition, claims 13-15 were added to emphasize these differences between *in-situ* oxidation and other metal oxides. The primary difference being that other metal oxides do not achieve full oxidation to provide an optimal resistance across the gap layer. In addition, claim 15 highlights that the metallic films are substantially free of unwanted non-oxidized Al or other metal atoms and contaminants due to the *in-situ* oxidation. Amendments to claims 1, 2, 7, 8, 9 and 12 are being made solely to clarify the aspect of metallic films and are not to be construed as limiting the scope of the claims as originally filed.

While the difference between oxygen doped metallic films and metal oxides is not immediately apparent, those of skill in the art who work with these materials will appreciate the difference. In support of these arguments, Applicant is submitting with this paper a declaration under 37 C.F.R. §1.132 showing that the metal oxide films used by Sasaki are patentably distinct from the claimed “*in-situ* oxidized metallic films.”

Claims 2, and 7-15 depend directly or indirectly from claim 1. Applicant submits that these claims are allowable for at least the same reasons as claim 1, as discussed above.

Should additional information be required regarding the traversal of the rejections of the dependent claims enumerated above, Examiner is respectfully asked to notify Applicant of such need. If any impediments to the prompt allowance of the claims can be resolved by a telephone conversation, the Examiner is respectfully requested to contact the undersigned.



Respectfully submitted,

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